UNIVERSITY OF CRAIOVA **Series: Geography**
UNIVERSITATEA DIN CRAIOVA **Seria: Geografie**

Vol. 13 (new series) – 2010
Vol. 13 (serie nouă) – 2010

WATER QUALITY INDEX - ASSESSMENT METHOD OF THE MOTRU RIVER WATER QUALITY (OLTENIA, ROMANIA)

INDICELE DE CALITATE A APEI – METODĂ DE DETERMINARE A CALITĂȚII APEI RÂULUI MOTRU (OLTENIA, ROMÂNIA)

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Abstract: The present paper aims at determining the water quality on the Motru river and at establishing its usage domains as water resource. The method consists in the computation of the Water Quality Index on the basis of the physical-chemical and biological quality parameters that were registered at the monitoring stations placed on the Motru river (Cloşani, Broşteni, and Fața Motrului). This index was computed for a long time interval (2000 – 2009) and it specifies the appropriate usage category, but it can also reveal the changes occurred at the level of the aquatic ecosystem. The novelty brought to the flowing water quality management consists in the underlining of the value of this index as potential indicator of the ecological state of the rivers.

Key-words: physical-chemical parameter, biological parameter, index, value, water quality, usage, the Motru river
Cuvinte cheie: parametru fizico-chimic, parametru biologic, indice, valoare, calitatea apei, folosință, râul Motru

1. INTRODUCTION

Water quality can be defined as a conventional ensemble of physical, chemical, biological and bacteriological features that are expressed as values and allow for the framing in a certain category, which expresses the possibility of its anthropic usage to meet a certain purpose.

The national framework for the establishment of the flowing water quality is presently represented by *The normative concerning the classification of surface water quality in order to establish the ecological state of the water bodies/Normativul privind clasificarea calității apelor de suprafață în vederea stabilirii stării ecologice a corpurilor de apă* (Order no. 161/February 16th, 2006) and by the methodology imposed by the *Water Directive* – The establishment of the ecological state of the surface water bodies. The Water Framework Directive was transposed in the Romanian legislation through the Law no. 310/2004, which modifies and completes the Law on Waters no. 107/1996.

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The Water Quality Index represents a numerical expression that is used in the flowing water quality assessment in the United States of America, Canada, Spain, France, Germany, Austria, Italy, Poland and Turkey.

Starting with 1965, Horton proposes the first computation formula with the intention of promoting an index that would comprise all data necessary for the establishment of the surface water quality (Liou et al., 2004).

The index was firstly used with the purpose of revealing the physical-chemical changes occurred at the level of the flowing water quality: *following the monitoring and quality management activities, there was attempted through mathematical methods to indicate the global quality state of the surface waters with the help of a qualitative index* (House, 1989).

The basic methodology used in the establishment of the value classes of the Water Quality Index was described for the first time by the Environmental Protection Agency, region 10, USA (periods: 1978/1979, 1979/80); it used various value intervals in order to set out the importance of each parameter in the computation of the index and, subsequently, it stipulated the establishment of a unique value - that of the index (Aroner, 2002).

In the '80s, on the basis of the methodology used by EPA, new limit values for the intervals were established depending on the local standards related to the flowing water quality (Hallock, 1990).

The water quality class is defined depending on the values of the physical, chemical and biological parameters and the establishment of the quality before the usage is crucial for various purposes, such as: drinking water, water used in agriculture, water used for leisure (fishing, swimming), or water used in industry (Sargaonkar and Deshpande, 2003).

The Universal Water Quality Index – UWQI was invented and then applied in order to ensure a simple method for the establishment of the quality of the surface water that is used for the water supply of the population (Hülya Boyacioglu, 2007). The subsequent development of the use of the Water Quality Index led to its use in the characterisation of the entire aquatic ecosystem (Cude, 2001).

Up to the present, at European level, three methods were intercalibrated for the *Geographical Intercalibration Group* Alpine area, in order to establish the ecological state of the sweet water through the usage of the phytoplancton as indicator - Brettum Index (BI) in Austria and Slovenia, PSI in Germany and Phytoplankton Trophic Index (PTI) in Italy (Lumb et al., 2006).

Study area

The Motru catchment area (S = 1,895 sq. km, L = 134 km) is located in the south-western part of Romania, within the Oltenian region. From the hydrographical point of view, it represents the largest sub-basin within the Jiu catchment area (direct tributary of the Danube, on the left).

The catchment's disposition in steps, on al altitudinal difference of about 1,700 meters (between 102 meters at the confluence with the Jiu and approximately 1,800 meters at the base of the Orlea Peak), makes the variety of geomorphologic units to influence the characteristics of the surface water drainage (Fig. 1).

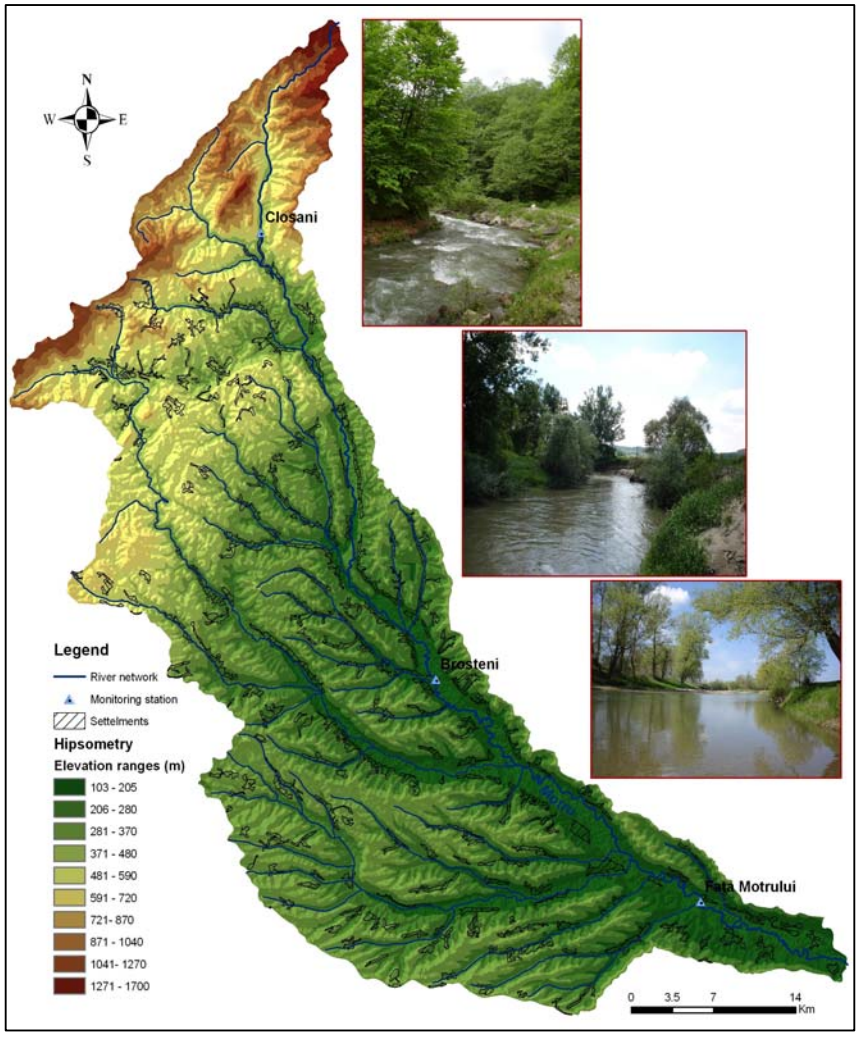

Fig. 1. Hypsometry of the Motru catchment
(processed after the SRTM elevation model at 90 meters)

The human stress on the surface water within the Motru catchment is mainly induced by the total number of inhabitants (111.068 persons), the urban inhabitants (32,314 persons) and by the organic loading that they generated through the industrial activities, land use and animal husbandry and, finally, through the degree of improvement of the hydrographical network.

2. DATA AND METHODS

According to the field literature, there are a number of computation formulas for the Water Quality Index, depending on the parameters that are considered, on

the comparative assessment methods and on the national norms concerning the establishment of the flowing water quality (Cude, 2001).

In most of the cases, this index represents a numerical expression used in the assessment of the flowing water quality, through the framing of the values in five classes on the interval going from 1 to 100; a certain quality state, respectively a usage domain correspond to each class (Adriano et al., 2006).

The raw values of each quality parameter must be compared with the standard threshold values that are taken into account for the computation of the index, in the view of the qualitative assessment. In all cases when the index must be determinate, the computation formula is the following:

$$WQI = 1/100\left(\sum_{i=1}^{9} q_i w_i\right)^2$$

WQI – the Water Quality Index

i – the quality parameter

qi – the registered value

wi – the rank of implication of the parameter in the computation formula

The values of the Water Quality Index that were thus obtained are distributed on a number of intervals, which render the quality of the respective water and the usage domain (Table no. 1): 10–25 percent - highly polluted; 26–50 percent - polluted; 51–70 percent - reasonable; 71–90 percent - good; 91–100 percent - very good (House and Ellis, 1987).

Starting with the year 2000, the environmental research centres tried to use a less difficult computation method and, presently, there are available two on-line computers: - WQHYDRO (Aroner, 2002);

- Monitoring the Quality of Surfacewaters, by Mr. Brian Oram, PG, According to the book *Field Manual for Water Quality Monitoring*, http://www.water-research.net/watrqualindex/index.htm, Pennsylvania, USA.

3. RESULTS AND DISCUSSIONS

The computation formula applied for the determination of the Water Quality Index on the Motru river includes nine physical-chemical and biological parameters that are registered by the local authorities (The Jiu Water Catchment Direction, The Laboratory for Water Quality Assessment) during any water quality measurement activity and it reflects, at the level of the value classes, the water usage potential.

The method chosen in the use of the Water Quality Index corresponds to that proposed by Harrison et al., 2000 and it involves four stages:

a. the selection of the parameters,

b. the bringing of the measurement units at the same scale,

c. the establishment of the weight of each parameter,

d. the computation of the Water Quality Index and the establishment of the usage domain.

Table no. 1

The interpretation scheme for the values of the Water Quality Index, on usage domains

Use score (percent)	PWS (Potable water supply)	FAWL (Fish and wildlife)	Industry	Recreation
100	No treatment required		Selected uses without treatment	
90		Suitable for all species of fish and wildlife		Suitable for all recreation activities
80	Minor purification		Minor purification if high quality water is required	
70		Doubtful for game fish. Supports populations of coarse fish	No treatment for most uses	Doubtful for direct contact sports
60	Conventional treatment			
50	Advanced treatment	Reasonable coarse fisheries	Advanced treatment required for most uses	Indirect and non-contact activities only
40	Doubtful use	Tolerant species only		
30			Only industries needing poor quality water	Non-contact uses only
20	Unacceptable	Unacceptable	Unacceptable	Unacceptable
10				

(Source: after House and Ellis, 1987)

a. The selection of the parameters was realised depending on the Global Quality Classes established through the *The normative concerning the classification of surface water quality in order to establish the ecological state of the water bodies/Normativul privind clasificarea calității apelor de suprafață în vederea stabilirii stării ecologice a corpurilor de apă.* During the last five years, the 2nd global quality class corresponds to the middle and lower sectors of the Motru water; this quality class is given by the chemical parameters of the nutrients.

At the same time, in the computation of the index there was not taken into account the microbiologic parameter – Total Coliforms, because it is monitored in the sections where the water is destined for the potable use.

Thus, the Water Quality Index for the Motru river is based o the following physical-chemical and biologic parameters:

- Physical parameters: Temperature (^{0}C), Slurry (mg/l).
- Chemical parameters: pH (U pH), Total phosphorus (mgP/l), Nitrates (mgN/l).

- Biologic/organic parameters: Oxygen saturation (percent),
Biochemical oxygen demand (mgO/l).

b, c. The bringing of the measurement units to the same scale and the establishment of the implication degree for each parameter were made in accordance with the previously presented methodology, which takes into account the importance of the parameter in the rendering of the sanogenesis state of the aquatic ecosystem. The value of the participation rank of each parameter in the computation of the Water Quality Index is:

- Oxygen saturation – 0.17;
- pH – 0.11; Biochemical oxygen demand (CBO5) – 0.11;
- Temperature – 0.10; Total phosphorus (P) – 0.10; Nitrates (NO_3^-) – 0.10;
- Slurry – 0.07.

d. The last stage was realised with the help of the on-line computer (http://www.water-research.net/watrqualindex/index.htm) proposed by Mr. Brian Oram from B. F. Environmental Consultants Inc., Pennsylvania, USA.

The computation of the Water Quality Index for the Motru river was realised through the introduction of the mean annual values of each quality parameter taken into account; the values were registered at the three monitoring stations on the Motru river (Cloşani, Broşteni and Fața Motrului).

The usage domain was established according to the quality intervals of the Water Quality Index (Table no. 2) in each section (50-74 percent – Moderate Quality and 75-94 percent Good Quality).

Table no. 2

Index value intervals and the corresponding quality category

Water Quality	Value intervals (percent)
Excellent	95-100
Good	75-94
Moderate	50-74
Marginal	25-49
Poor	0-24

At Cloşani monitoring station, located on the upper course, the Motru water quality is good, according to the mean annual values of the index during the 2000 – 2009 period (Fig. 2). The year 2007 is individualised through values that are closer of the interval characteristic to the moderate quality (WQI-84), fact which is explained by the decrease of the values of the chemical parameters (Nitrates: 2.094 mgN/l in 2006 and 1.749 mgN/l in 2007) and by the increase of the physical ones (slurry: 31.5 mg/l in 2006 and 29.2 mg/l on 2007).

In the middle and lower courses, because of the increased human impact on the water resources, the values of the Motru Water Quality Index show obvious annual oscillations (Fig. 3, Fig. 4). Thus, between 2000 and 2009 there are to be remarked the important variations registered during three years (2005, 2006, and 2007).

The low value of the index registered in 2006 at both monitoring stations (Broşteni – 88 percent in 2000, 80 percent in 2006 and 86 percent in 2007; Fața

Motrului – 87 percent in 2005, 81 percent in 2006 and 85 percent in 2007) is given by the contribution brought in the computation formula by two qualitative parameters (Fig. 5, Fig. 6): the biochemical oxygen demand (Broşteni – 1.25 mgO/l in 2005; 2.27 mgO/l in 2006; 1.31 mgO/l in 2007 and Fața Motrului – 1.5 mgO/l in 2005; 2.11 mgO/l in 2006; 1.35 mgO/l in 2007) and the nitrates (Broşteni – 0.704 mgN/l in 2005; 5.078 mgN/l in 2006; 2.811 mgN/l in 2007 and Fața Motrului – 0.912 mgN/l in 2005; 5.530 mgN/l in 2006; 3.134 mgN/l in anul 2007).

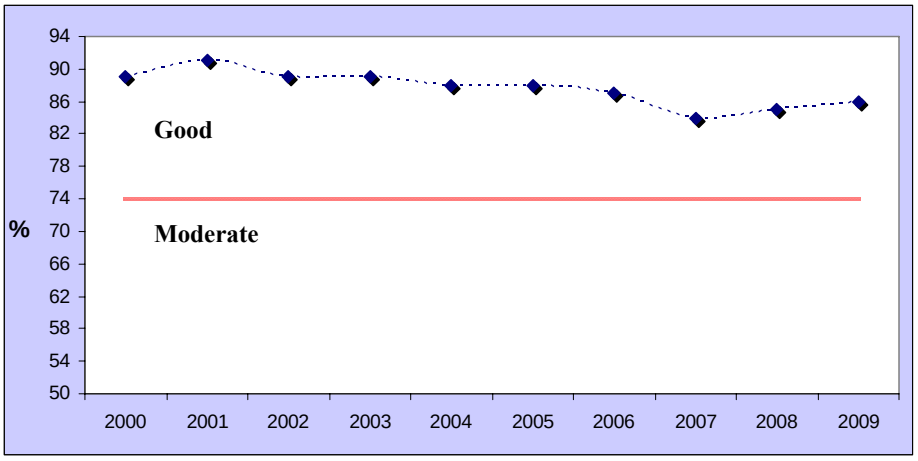

Fig. 2. The variation of the Water Quality Index on the Motru, at Cloşani station, in 2000 – 2009 period

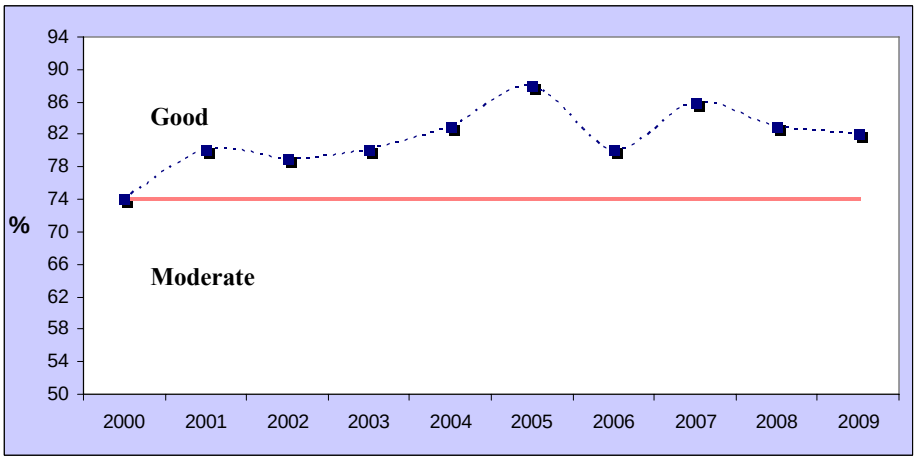

Fig. 3. The variation of the Water Quality Index on the Motru, at Broşteni station, in 2000 – 2009 period

For 2000, at both Broşteni and Fața Motrului stations, the value of the index corresponds to the moderate quality class. The nutrients, respectively the values of the nitrates are also responsible in this case for influencing the quality category

(nitrates: Broşteni – 5.525 mgN/l in 2000 and 3.418 mgN/l in 2001; Fața Motrului – 6.052 mgN/l in 2000 and 4.688 mgN/l in 2001).

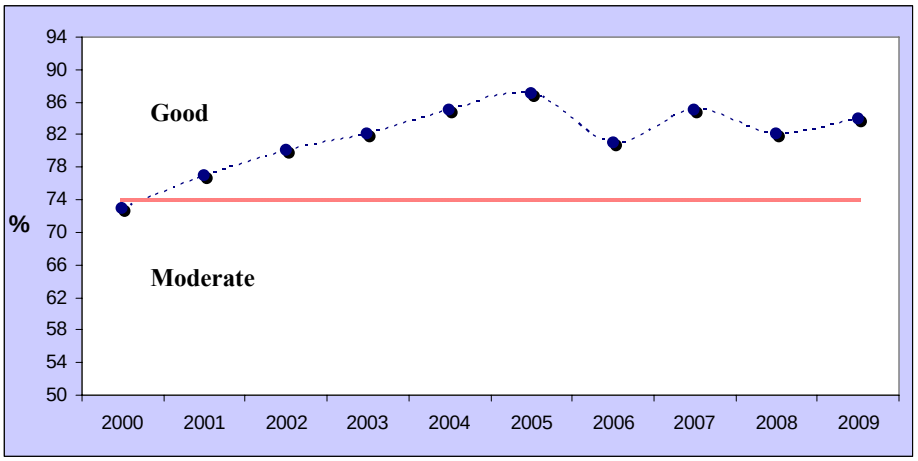

Fig. 4. The variation of the Water Quality Index on the Motru, at Fața Motrului station, in 2000 – 2009 period

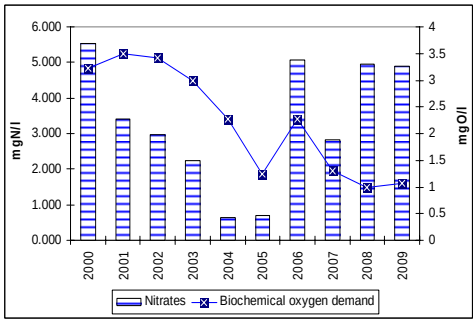

Fig. 5. The variation of the nitrates and of the biochemical oxygen demand at Broşteni station (2000-2009)

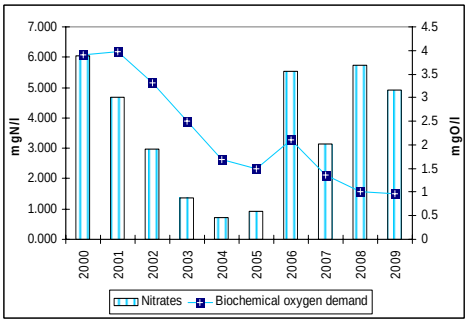

Fig. 6. The variation of the nitrates and of the biochemical oxygen demand at Fața Motrului station (2000-2009)

As underlined by the previous observations, the water quality of the Motru river is directly influenced by the regime of the biogenic and organic substances. The content of the biogenic elements within the rivers is connected to the appearance and the decomposition of the organic substances. As a consequence, the regime of the biogenic elements depends on the vital activity of the organisms (Trufaş V., 1985). In the water of unpolluted rivers, the concentration of nitrates often oscillates within the limits of a few tenths of mg/l.

The main cause for the loading of the flowing waters with nitrates consists in the eviction of the urban waste waters. This is the reason for which the content in $NO_3^{-o}$of the river water often surpasses 1 mg/l and even 10 mg/l.

The Broşteni and Fața Motrului monitoring stations are located downstream of the most important urban settlements (expressed in equivalent inhabitant number) within the Motru catchment area, respectively Motru and Strehaia towns.

Motru town (22,472 inhabitants in 2009) is the only settlement that has a waste water treatment plant, but although it is also foreseen with a secondary phase, because the aeration tanks lack the operation capacity, the efficiency of the treatment plant is reduced only to the mechanical stage. In Strehaia town (7,697 inhabitants in 2009), the sewerage system does not benefit of a waste water treatment plant.

According to the assessments performed by the Analysis Laboratory, Romania Waters National Administration – Jiu Water Branch, in 2009, on the pollution of the two town administrations (S. C. REZOPREST S. A. Motru and S. C. FLAPS Strehaia), there had been registered exceeds as compared to the limit values of NTPA 001/2002 to the following parameters: CBO5=165 mg/l, slurry=108 mg/l (Motru); CBO5=42 mg/l, chemical consume of Oxygen (CCOCr)=116,6mg/l and slurry=92 mg/l (Strehaia).

The interpretation of values corresponding to the Water Quality Index on the Motru, on the basis of the scheme proposed by House and Ellis (1987) allows for the establishment of the usage domain for the river water as natural resource. During the years when values above 90 percent were registered, the water of the Motru river was good for all recreation activities and convenient for all fish species and aquatic fauna, while in the case of the values comprised between 74 and 90 percent, the water situation was uncertain for aquatic sports that imply the direct contact with the water and for fishing, only supporting the population with sweet water fish species. The usage degree for industry and water supply was not established because the water of the Motru river is not used in this type of activities.

4. CONCLUSIONS

The use of the Water Quality Index in the determination of the water quality on the Motru river corresponds to the present tendencies within the field of water resources management; thus, it is attempted at a more important scale to assign chemical and ecological importance to the classical parameters related to the physical and chemical quality. The advantages of using this method were numerous, given the fact that the Water Quality Index:

- includes more variables in only one number;
- brings to the same measuring unit more parameters related to the water quality;
- offers the possibility to compare in temporal and spatial terms the quality of more water bodies or that of a single one;
- offers an image of the water usage degree is various fields/purposes.

Just as the European Union, through the *Water Framework Directive*, tries to stimulate the achievement of a good quality for all water bodies within its territory, at national and regional level it must be assigned great importance to the consideration of the global quality state, present and past, for the establishment of the adequate plans for the water resources management activities.

ACKNOWLEDGEMENTS

The research was conducted by the PhD student Ionuş Oana within the framework of a grant offered by the Simion Mehedinți Doctoral School – *nature and sustainable development* (Faculty of Geography, University of Bucharest), project co-financed by the EUROPEAN SOCIAL FUND through the *Sectorial Operational Programme for Human Resources Development 2007-2013*, Contract POSDRU/6/1.5/S/24/7546.

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